PSWN

Public Safety Wireless Network

Commercial Wired Service Assessment

July 1999

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1. INTRODUCTION

The public safety community relies on wireline technologies to provide land mobile radio (LMR) internetworking and interfaces to LMR repeaters, base stations and dispatch centers. In addition, public safety users rely on voice and data wireline networks to ensure access to public safety databases, such as the National Criminal Information Center (NCIC), and to provide voice, data, and video services to public safety locations. This report discusses the wireline technologies that provide the underlying infrastructure and wireline services.

1.1 Purpose

The purpose of the *Commercial Wired Service Assessment* report is to discuss traditional and emerging commercially available wireline technologies and their applications. This report looks at the commercial wireline technologies that provide LMR connectivity. It discusses the evolution of wireline technologies, ranging from analog circuits to sophisticated digital packet switches resident on the Internet. In addition, the report describes wireline media and transmission and switching technologies that compose today's networks. Finally, this report compares wireline technologies, describing their benefits and limitations.

1.2 Background

Wireline technologies continue to evolve from pole-mounted copper lines. This has resulted in dramatic changes in the underlying private and public switched network (PSN) infrastructure and the expansive Internet infrastructure. The rapid evolution of these technologies has been driven by demand for higher-bandwidth services; the proliferation of data, imaging, and video applications; and the implementation of advanced, digital technologies that improve efficiency and support greater capacity. The public safety community primarily uses wireline technologies to provide connections within and between LMR networks. For example, these technologies may support the implementation of new digital LMR networks, provide LMR network interconnection, and offer a mechanism to interoperate diverse LMR networks through a common wireline interface.

1.3 Organization

This report is organized into 4 sections and one appendix. Section 2 discusses the application of wireline technology to the public safety community. Section 3 discusses the evolution of wireline technologies, and describes wireline media, transmission, and switching technologies. Section 4 characterizes and compares similar wireline technologies using a set of performance metrics. Section 5 presents a summary of the document. Appendix A describes the use of wireline technologies to support public safety testbeds.

2. APPLICATION OF WIRELINE TECHNOLOGIES TO PUBLIC SAFETY

Public safety users rely on a mix of wireline technologies to fulfill communications needs during emergencies and for day-to-day operations. This section describes the application of wireline technologies to support public safety communications. Specifically, this section describes how wireline technologies:

- Provide interconnections within public safety LMR networks
- Connect public safety LMR networks
- Connect public safety LMR networks to external wireline networks and databases
- Provide interconnections within commercial wireless networks.

The use of private and public networking is a central distinction in this report. Private networking addresses privately owned communication transport facilities, such as a point-to-point microwave system would provide. These circuits are usually available only to the network owner. Public networks are provided by common carrier or service providers offering services available to the general public for lease. System planners do have combinations of both private and public wireline facilities. A public service leased line can be a subset of an integrated private network. Public networks, designed and implemented by commercial wireline carriers including the PSN and the Internet, provide commercial services and leased line services to any customer.

2.1 Providing Wireline Interconnections Within Public Safety LMR Networks

A variety of wireline technologies are used to connect LMR equipment and facilities within public safety LMR networks. Some public safety organizations are modernizing their wireline facilities or replacing point-to-point microwave links with dedicated wireline circuits to improve bandwidth and performance and, in some cases, to release microwave spectrum which has been refarmed as mandated by the Federal Communications Commission (FCC). An example of a SONET wireline service as a subset of an LMR system is illustrated in Exhibit 1.

Public safety organizations can use private wireline technologies to connect LMR network elements within a public safety network or lease PSN circuits to connect geographically diverse public safety locations. If private wireline facilities are used, the specific technology installed is based on the most cost effective solutions available that meet the specific need. For example, early LMR network implementations used bare copper lines supporting dc-current signaling to connect LMR network components within a premise. More rigorous system requirements dictated the need for remote located radio control lines that supported in-band tone control, which drove the need for 3002 conditioned analog voice grade circuits. Networks installed in the 1980s use a mix of these analog copper and conditioned 3002 lines and digital fractional T1s (FT1) to connect LMR network components.

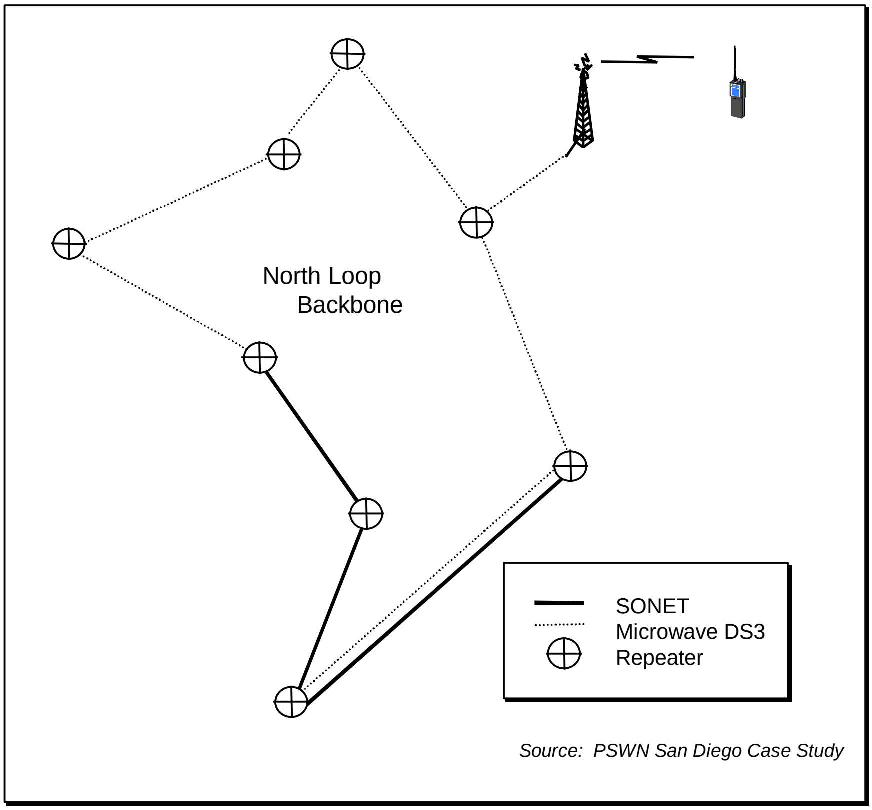

Exhibit 1
Wireline Technology Partially Supporting an LMR Network

2.2 Connecting Public Safety LMR Networks

When Public safety organizations use wireline technologies to interconnect different LMR networks, a specific interface point needs to be established along with proper radio control hand-off logic and voice level balancing. This is necessary in cases where public safety organizations use different types of leased lines from a variety of local telephone companies. As an example, the United States Navy (USN) Border Interoperability Project uses a mix of wireline transmission services to connect multiple LMR networks to the USN Console Communications Electronics Board (CEB). The CEB is the common interconnect point for control logic and voice balancing. Exhibit 2 illustrates the connectivity among the USN Console CEB, the Naval Station (NAVSTA) Security Console CEB, the city of San Diego Console CEB, and the radio facility at Mount Soledad where various federal, state and local agencies have co-located radio assets. Employing wireline technologies to interconnect different LMR networks in this way may be an effective alternative to achieving interconnection and interoperation among public safety users.

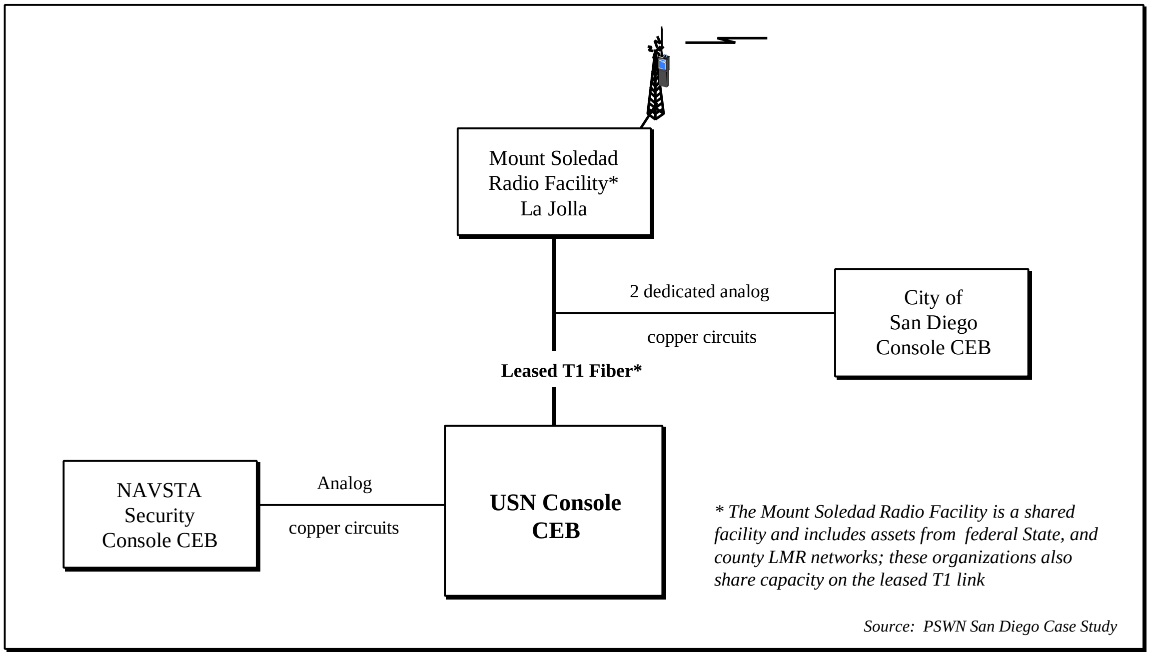

Exhibit 2
The Use of Wireline Technologies to Connect LMR Networks as Part of the San Diego Testbed

2.3 Connecting Public Safety LMR Networks to External Wireline Networks and Databases

Public safety users require external connections to private networks and the PSN for selective voice calls, and occasional data applications. To access external networks, connections are typically provided at dispatch centers through manual or automated patching. In these cases, private or public leased lines are provided between the LMR network interface (usually the dispatch center) and the external circuit demarcations. When public safety users need access to the PSN to communicate with users outside their LMR network, the dispatch center may provides a phone patch between the LMR user and the PSN. For the external data requirements, dedicated data services are generally provided for access to the wireline data network via a router or gateway on the agency internal LAN. One specific example is accessing the NCIC from the LMR network directly.

The Iowa Project uses wireline switch and transmission services from the local telephone company to connect the State of Iowa LMR system to external networks and databases. Specifically, the Iowa Project uses frame relay data switching and SONET OC-3 transmission links. The State of Iowa uses these wireline technologies to connect their LMR network to the PSN, various Iowa networks, and external databases, such as the NCIC. Exhibit 3 illustrates this configuration.

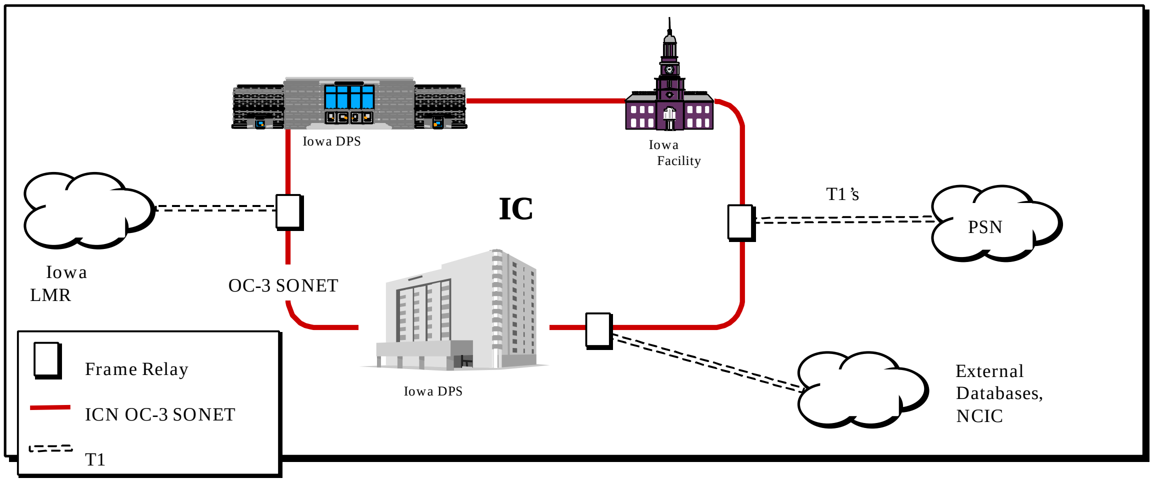

Exhibit 3
LMR External Wireline Connections as Part of the Iowa Project

2.4 Providing Wireline Interconnections Within Commercial Wireless Networks

Public safety users rely on commercial wireless services to meet some communication requirements. Commercial wireless networks, such as cellular, personal communications services (PCS), cellular digital packet data (CDPD), and mobile satellite services (MSS), require wireline technologies to provide interconnections among network components and locations. For example, wireline facilities interconnect cellular base sites and also connect these base sites to mobile switching centers (MSC). Commercial wireless service providers typically use digital fiber connections, where available. In addition, commercial providers use wireline facilities to connect to local service provider's PSN networks. Ehibit 4 illustrates wireline interconnections within a cellular network offering cellular and CDPD services.

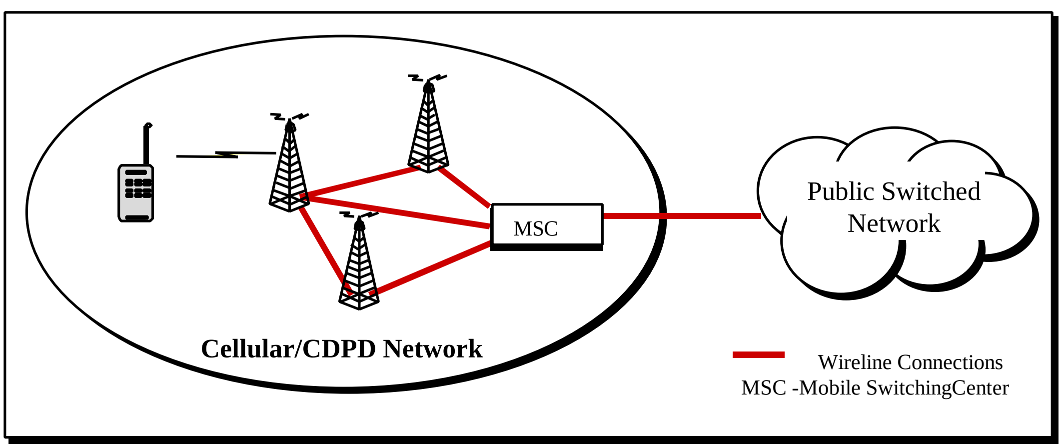

Exhibit 4
Wireline Connections Within a Cellular Network

3. WIRELINE TECHNOLOGIES

Wireline technologies used to support private, public, and Internet networking differ in their level of complexity and capability. Technologies include those embedded in current LMR networks, as well as emerging technologies likely to be implemented in the newest agency networks, the PSN, and the Internet. Wireline technologies may range from copper lines supporting dc-current signaling to sophisticated cell-based switching systems. This section discusses the evolution of wireline technologies, describes the physical media supporting wireline technologies, and discusses transmission and switching technologies.

3.1 The Evolution Of Wireline Technologies

Wireline technologies are rapidly evolving to meet ever-increasing bandwidth and networking demands. Private and public networks supporting the public safety community range from transmission links supporting legacy public safety systems to switching systems providing the backbone routing and intelligence for public safety WANs. Exhibit 5 illustrates the general evolution of wireline technologies. In broad terms, wireline technologies are rapidly evolving because of the following:

- Increasing bandwidth demands associated with current and emerging data and video applications

- Increasing need to achieve greater levels of reliability through the use of advanced transmission, routing, and switching techniques

- Technological advances that allow networks to support advanced applications, increase network capacity, and gain network efficiencies

- Advances in switching technologies that allow networks to integrate voice, data, and video applications onto a single backbone

- The need to support a wide range of user networking needs, while providing improved economies to allow users to refresh technologies to support user requirements.

3.2 Physical Media

In great measure, the underlying physical media dictates the performance of wireline technologies. The media, which include copper, coaxial cable, and fiber, have different physical properties that result in different bandwidth, cost, and integrity characteristics. Exhibit 6 illustrates the physical characteristics of copper, coaxial cable, and optical fiber. In addition, these media are implemented in different network segments or environments. The implementation of a particular media has typically depended on the requirements of the application, limited by the technology available at the time of implementation.

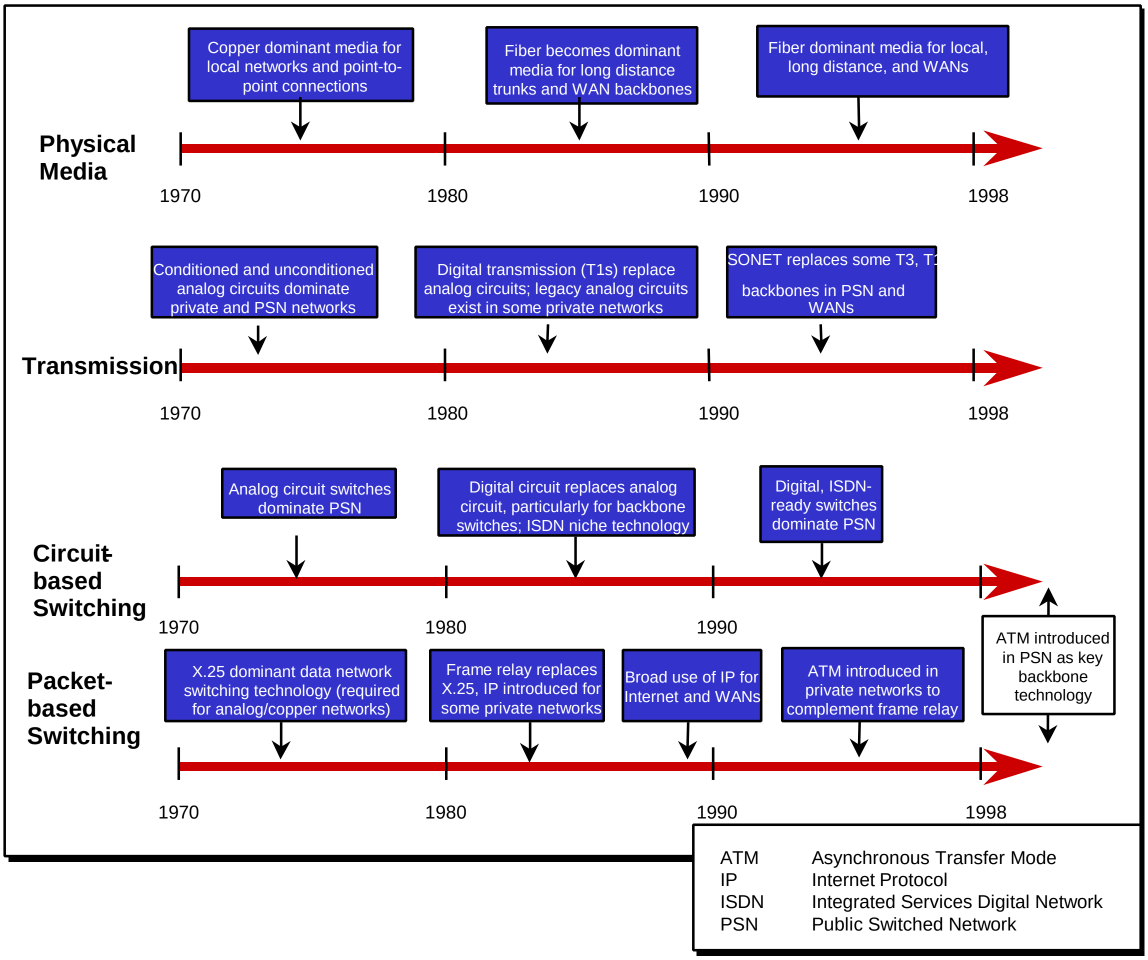

Exhibit 5
The Evolution of Wireline Technologies

	Copper	Coaxial Cable	Optical Fiber
Distance	• Amplifiers required over short to moderate distance	• Amplifiers or repeaters required over moderate to long distance	• Repeaters required over moderate to long distance
Data Capacity	• Nominally 9.6 kbps	• Nominally 10 Mbps	• Up to Terrabit (10^{12})
BER	• BER = $1x10^{-5}$	• BER = $1x10^{-6}$	• BER = $1x10^{-9}$
Fragility	• Moderately rugged; older systems susceptible to rain and water damage	• Rugged, can support outdoor deployment and withstand some physical contact	• Fragile-cable sheath protection required

Exhibit 6
Physical Characteristics of Copper, Coaxial Cable, and Optical Fiber

3.2.1 Copper Wire

Copper wire forms the underlying physical infrastructure for residential telephone service and provides the private networking for analog legacy LMR systems. The exact type of copper in private LMR networks depends on a number of factors, including the copper cables available or in routine use at the time of installation, and whether the service was provided by a telephone company or installed privately. The different copper technologies, their typical application to LMR systems, and engineering considerations are illustrated in Exhibit 7. Copper is typically configured in single pair (2-wire) or dual pair (4-wire), depending on interface and application needs. A copper two-pair 3002 circuit typically provides from 300 to 3000 Hertz (Hz) of bandwidth and is capable of passing up to 9.6 kbps of data, without special conditioning.

Type	Common	Engineering
Copper Lines	• Used most For internal Facility wiring	• Use DC voltage for simplex signaling • Copper lines are typically pole mounted on telephone company poles or LMR facilities
Voice Grade Lines - 3002 (Unconditioned)	• Used for telephone systems and private networks • Tones are used instead of DC current • Users may acquire 2-wire and 4-wire lines, on implementation needs	• Equalization equipment is recommended to limit attenuation • Specifications are published in Bell Systems Technical Reference PUB 41004 • Voice band is 300 Hz to 3000 Hz • Difference in frequency between modulating and demodulating carriers may degrade some data demodulation processes • Line conduits should be encased in protective sheaths and conduits to protect the lines from moisture • Lines should be placed at least 12” below ground to reduce the risk of line cuts from digging or limit the exposure of the conduit if ground erosion occurs
Conditioned 3002 Lines	• Used primarily for data transmission (e.g., signals, telemetry, remote monitoring information) • Conditioned lines include C1, C2, C3, C4, C5 lines: C1 and C2 lines are recommended for LMR networks • Users may acquire 2-wire and 4-wire lines, depending on implementation needs	• Conditioning improves the frequency response of telephone lines and reduces envelope distortion • Line conduits should be encased in protective sheaths and conduits to protect the lines from moisture • Lines should be placed at least 12” below ground to reduce the risk of line cuts from digging or limit the exposure of the conduit if ground erosion occurs

Exhibit 7
Copper Media Characteristics

3.2.2 Coaxial Cable

Coaxial cable typically provides private networking within facilities and forms the distribution plant for cable TV systems. For government agencies, coaxial cable typically provides "ruggedized" LANs or circuits to support mobile or deployed users, or where LAN wiring is outside facility walls and vulnerable to physical damage. Coaxial cable is constructed with a concentric center and an outer shield which are separated by a dielectric such as air or polyfoam. Baseband signals are carried along the coaxial cable with the lower frequencies present on the outer surface of the inner conductor and the higher frequencies present on the inner surface of the outer conductor due to skin effects. The outer channel serves as a ground. Many of these cables or pairs of coaxial tubes can be placed in a single outer sheathing.

3.2.3 Optical Fiber

Optical fiber is configured in glass fiber strands and transmits information through light pulses. It is becoming the primary physical medium to support private, PSN, and Internet backbones because of the associated bandwidth gains and data integrity. Because fiber is relatively fragile, it is implemented with suitable protective sheathing.

3.3 Wireline Transmission Technologies

Transmission technologies provide the physical connection among network nodes or customer facilities. In broad terms, transmission technologies structure the information sent over the physical media. Transmission technologies include conditioned and unconditioned analog circuits; digital T1, T3, and fractional T1 (FT1) systems; and SONET systems.

3.3.1 Analog Circuits

Conditioned and unconditioned 3002 analog circuits provide connectivity within public safety locations for legacy systems and serve as the local distribution plant for residential telephone service. Conditioned circuits include amplifiers to recondition signals and reduce signal noise, and include amplifiers and equalizers to enhance the signal to noise ratio and improve the linear bandpass characteristics of the circuit. Analog circuits typically use copper lines. The typical unconditioned analog circuit operates from 300 to 3000 Hz and usually support nominal bit rates of 9.6 kbps.

Analog circuits also support legacy analog LMR systems. In most cases, these circuits are replaced as part of an overall system upgrade, as the circuits degrade, or as bandwidth or performance needs evolve. Analog circuits may also provide connectivity between locations, either through private circuits or through dedicated circuits provided by telephone companies. Analog circuits can support bulk encryption; this is accomplished by deploying digital bulk encryption equipment at public safety network interface points.

Legacy wireline mutiplexers and cable systems carry numerous analog voice channels using frequency division multiplexer (FDM) schemes. FDM is composed of a base group of 12 channels and supergroups of 60 channels each. The parallel open wire pole multiplexers typically carry 12 analog voice channels over a 100 Khz carrier. These parallel wire lines tranpos every few miles, as determined by the carrier frequency, to prevent ringing oscillations that may cause interference among FDM channel slots.

3.3.2 Digital T1, T3, and FT1 Systems

Digital T1, T3, and FT1 transmission systems replaced analog circuits to improve performance and bandwidth, and to take advantage of the network efficiencies provided by digital transmission. These systems can support both digital and analog information by implementing analog/digital translators at the appropriate network interface. Digital T1, T3, and FT1 transmission systems use time-division multiplexing (TDM) where respective channel slots are sequentially sampled and assembled as frames in a data stream. These technologies require digital transmission equipment at each origination and termination node. T1 transmission stream consists of 24 contiguous 64 kbps channels that are multiplexed to create an aggregate 1.544 megabits per second (Mbps) data rate. T3 provides 44.736 Mbps. FT1 allows users to bundle the 64 kbps channels to provide needed bandwidth but avoid the cost of a full T1.

Digital T1, T3, and FT1 systems are used to provide private, dedicated transmissions, and public network trunking. For private dedicated circuits, T1 electronics are installed at the user facilities. T1 technologies can also support bulk encryption at the public safety network interface points. In general, carriers are replacing T1 and T3 trunking with SONET transmission technology.

FT1	Nx64 kbps
T1	1.544 Mbps
T3	44.736Mb

Exhibit 8
Time Division Multiplex Transmission Rates

3.3.3 SONET

SONET is the U.S. standard for synchronous data transmission on optical media. SONET uses digital TDM techniques to transmit data, and defines a set of transmission rates known as "optical carrier (OC) levels." Exhibit 9 lists the different SONET OC rates. SONET can support both digital and analog information by implementing analog/digital translators at the appropriate network interface.

OC-1	51.84 Mbps
OC-3	155.25 Mbps
OC-12	622.08 Mbps
OC-48	2.48Gbps

Exhibit 9
SONET OC Transmission Rates

SONET is becoming the dominant transmission technology for the PSN, Internet, and some WAN backbones; current long distance and local interswitch networks are typically 100 percent SONET. Public safety organizations can use SONET as a WAN technology, and to provide leased circuits to connect networks. SONET technologies can support bulk encryption; this is accomplished by deploying bulk encryption equipment at public safety network interface points. Finally, PSN carriers are upgrading current SONET transmission links to SONET rings to improve reliability and enhance routing capabilities.

3.3.4 Integrated Systems Digital Network (ISDN) Transmission

Integrated Systems Digital Network (ISDN) is a digital network technology that provides a range of capabilities to support voice, data, and video applications. Although ISDN is typically associated with switching, it can also provide point-to-point digital transmission capabilities. For example, ISDN transmission links can provide connections between LMR networks. This is typically accomplished through leased circuits and by using ISDN interface cards or ISDN modems at the LMR network interface point. These links can support capacity from 64 kbps to 1.544 Mbps, depending on user needs. ISDN can support analog and digital information by implementing analog/digital translators at appropriate network interface points.

3.4 Switching Technologies

Network switching technologies provide the capability to route information from origination to destination. There are two primary switching types: circuit switching and packet switching. Each are described below.

3.4.1 Circuit Switching

Circuit switching includes analog and digital plain old telephone service (POTS) and ISDN switching, and typically supports voice, fax, and dial-up communications. Each are described below.

3.4.1.1 Analog and Digital Circuit Switching

Analog and digital POTS circuit switching provide the fundamental technology for the PSN. Circuit switching, through the use of signaling, sets up a circuit for each call session. This circuit is maintained for the duration of the call, then released. Circuit switching is used primarily for voice and fax communications. It can also be used for dial-up modem access to either private networks or the Internet.

Generally, telecommunications services are delivered similarly by analog and digital POTS. In fact, analog switching is rapidly being replaced with digital switching; analog switching is likely to disappear except in rural areas. The improvement associated by upgrading to digital switching is realized by the telephone companies, which gain the efficiency and capacity associated with digital technologies. In addition, digital POTS may provide the necessary platform to offer advanced signaling features and services, such as call forwarding and caller ID, that are offered today.

3.4.1.2 ISDN Switching

In addition to providing digital transmission capabilities, ISDN can also provide digital network switching. ISDN switching increases the capacity provided by POTS services and supports voice, data, and video applications. As illustrated in Exhibit 10, ISDN is provided in two service types: Basic Rate Interface (BRI) and Primary Rate Interface (PRI). BRI is typically used for user-to-user communications or for low speed circuits (64 kbps - 128 kbps) while PRI bundles multiple BRI circuits or is used for higher bandwidth applications, such as videoconferencing.

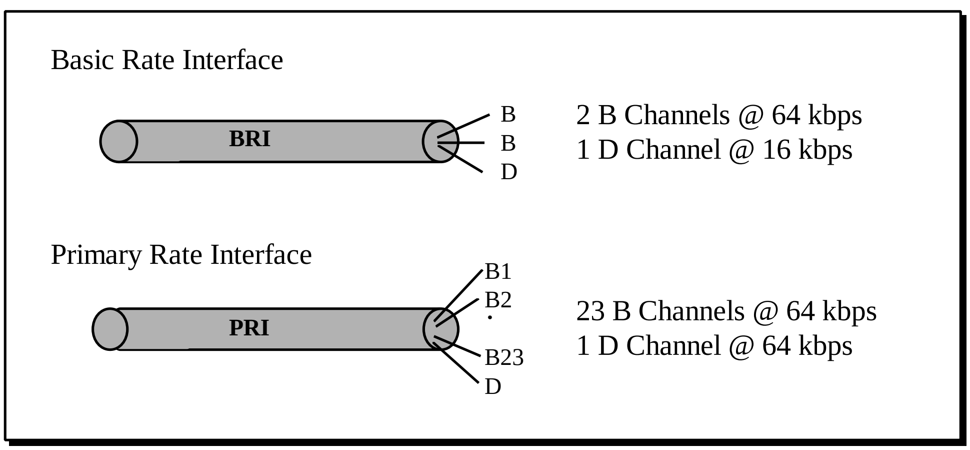

Exhibit 10
ISDN Switching

3.4.2 Packet-Based Switching

Packet-based switching, in this report, refers to the different data switching techniques used for user WANs and the Internet, including X.25, frame relay, and Asynchronous Transfer Mode (ATM). Also, this section includes a discussion of the Internet Protocol (IP), which is implemented within other packet switching systems, such as frame relay and ATM.

3.4.2.1 X.25 Switching

X.25 switching is one of the initial packet switch technologies used to support private data WANs. It was designed to support network infrastructures (and physical media) that are likely to induce link errors and user applications that do not require high capacity. Therefore, as illustrated in Exhibit 11, the X.25 packet includes the information field and an overhead field to provide error detection/error correction. In addition, X.25 provides a maximum throughput of 56 kbps. Finally, X.25 structures the link in channels (unlike TDM in which the data is structured by time slots), creating a set of 56 kpbs channels.

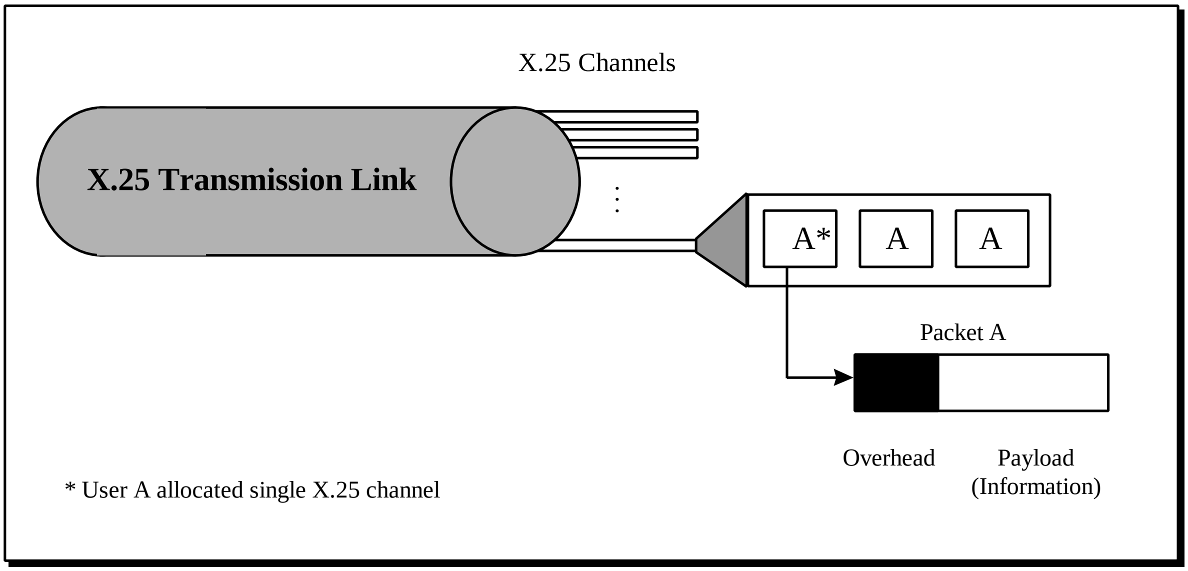

Exhibit 11
X.25 Switching

X.25 was the primary switching technology for legacy data networks and the National Science Foundation Networks (NSFNet) and the Defense Advanced Research Project Network (DARPANet) which, together, have evolved into today's Internet. Because X.25 cannot efficiently support the higher capacity data applications common today, X.25 has generally been replaced by "fast packet switching techniques," such as frame relay and ATM. However, most systems are backwards compatible to X.25, so in many cases it remains a "least common denominator" interconnection technology.

3.4.2.2 Frame Relay Switching

Frame relay switching uses variable length frames to transmit information within data networks, as illustrated in Exhibit 12. Frame relay evolved from X.25 as fiber became the dominant media for data networks and organizations implemented applications requiring greater bandwidth and performance. Because fiber incurs significantly fewer data errors, frame relay does not require the robust error checking/error correction techniques used by X.25. Therefore, as shown in Exhibit 12, the frame relay overhead is greatly reduced. Also, frame relay transitioned from X.25 dedicated channel data structures to statistical multipexed TDM-based data structures. In this way, frame relay is able to support greater bandwidths, from 16 kbps to 12 Mbps.

Frame relay networks provide the switching backbone for private networks, virtual private networks (VPN), and the Internet. VPNs are software partitioned switched networks that support multiple private networks. Carriers own and operate the network switches. To the user organization, the network performs as a private network. Frame relay VPN providers offer an agreement to ensure sufficient bandwidth to support user requirements. This bandwidth agreement is based on the user's committed information rate (CIR).

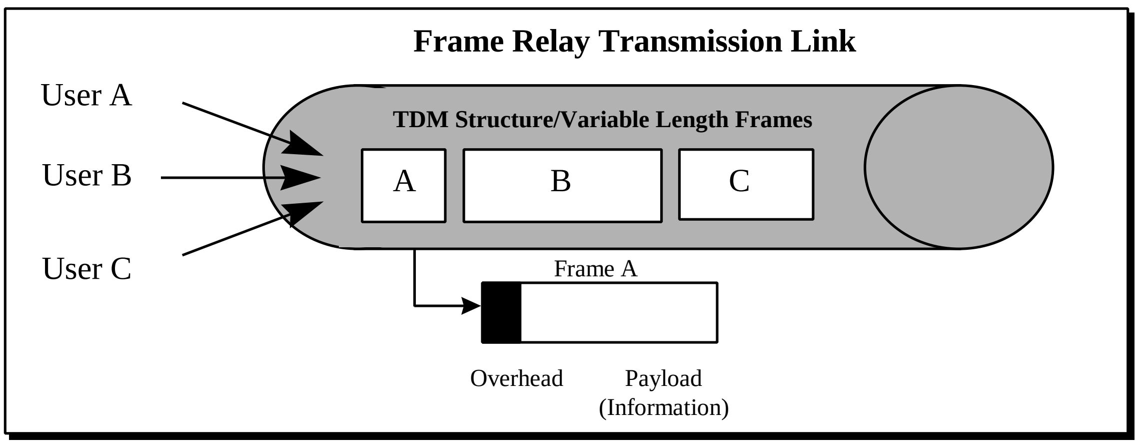

Exhibit 12
Frame Relay Switching

3.4.2.3 ATM Switching

Asynchronous Transfer Mode (ATM) is a cell-based switching technology. The ATM cells, illustrated in Exhibit 13, are 53 bytes in size: 48 bytes include the “payload” or actual information and 5 bytes are set aside for administrative, routing, and protocol information. ATM provides an integrated platform that can simultaneously support voice, data, and video applications and services and is designed to provide high-speed network throughput. Additionally, ATM does not conduct robust error checking and resolution. As a result, ATM is typically implemented in fiber optic networks that can support higher speeds and produce minimal transmission errors. Current ATM systems can provide up to 2.48 Gbps.

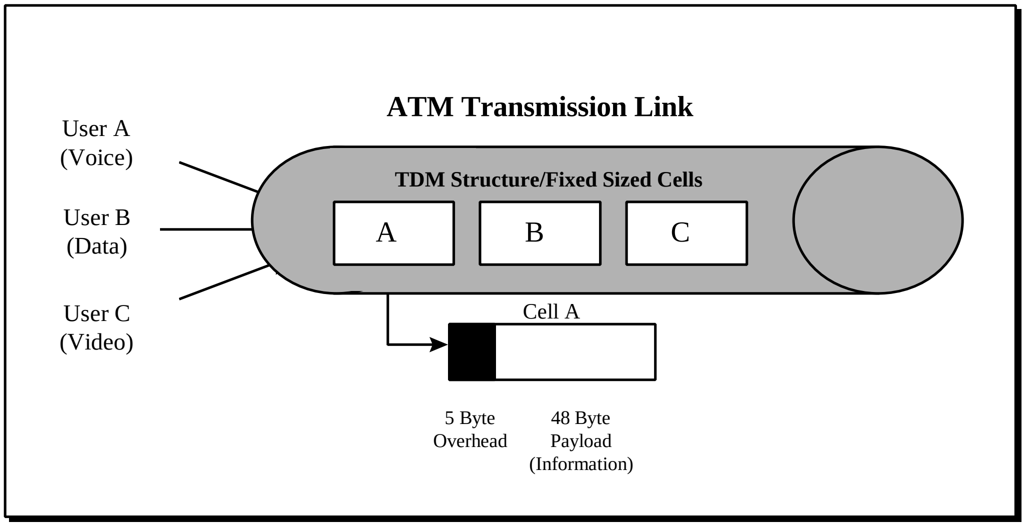

Exhibit 13
ATM Switching

The ATM Forum, an industry forum composed of regulators, manufacturers, carriers, and user community representatives, is recommending ATM standards. To date, standards have been established for data services and applications. The ATM Forum is also recommending standards for voice and video applications, which is the final step necessary for ATM to be broadly implemented.

- ATM is considered the next-wave technology for the PSN, the Internet, and for some private and VPN WANs. It is a crucial technology that allows carriers to use a single network backbone to provide and support voice, data, and video services and applications.

3.4.2.4 Internet Protocol (IP) Implemented On Packet-Based Switching

IP is a common protocol used to support network interconnection and interoperability. IP is implemented on data switching structures, such as frame relay and ATM, by placing IP network cards in the network switch. In this way, IP takes advantage of the switching structures and bandwidth provided by frame relay and ATM and provides network interoperation among different networks. IP is also the underlying protocol for the Internet.

4. ANALYSIS CONSIDERATIONS AND CHARACTERIZATION

The rapid growth of new wireline technologies and services is causing fundamental changes in the PSN, private networks, and the Internet. Service providers and equipment vendors offer a variety of wireline technology solutions for private networking and for commercial voice, data, and video services. LMR system planners may be able to select a wide range of wireline solutions as they plan for system replacement. This section is designed to compare similar technologies to provide background information to system planners.

As new wireline technologies are introduced into the market, customers have to evaluate them and tradeoff the different alternatives that may meet their requirements. A set of analysis considerations can be applied to compare similar technologies or services. For example, metrics can be used to evaluate, compare, and contrast different packet-based switching solutions (e.g., X.25, frame relay, ATM, and IP switching). The evaluations and comparisons are presented in a set of matrices that provide a qualitative description as to how the technology performs against the analysis considerations. This section describes the set of considerations and uses the metrics to evaluate and compare technologies and services.

4.1 Analysis Considerations

The analysis considerations are intended to broadly reflect the requirements of the public safety community and provide a structure to highlight the technical and performance attributes and characteristics of alternative technologies and services. Analysis considerations can aid in effectively characterizing, comparing, and contrasting wireline technologies. The analysis considerations include:

- **Ubiquity:** Measures whether the technology or service is available for any location nationwide

- **Bandwidth/Capacity:** Bandwidth measures the upper limit bandwidth of the physical link. Capacity measures the gains achieved by applying protocols to the transmission link.

- **Physical Medium:** Identifies the transmission media typically needed or used to support the technology

- **Cost:** Describes the current service cost; additionally, describes how the service is priced (e.g., whether a data service is typically priced per port or per usage)

- **Customer Premise Equipment (CPE):** Specifies the customer equipment (e.g., ISDN equipment) needed to provide the service, and the approximate cost of the equipment

- **Typical Implementation:** Identifies the typical application (e.g., private networking vs. PSN backbone technology) for the technology

- **Applications Supported:** Identifies the range of applications (e.g., voice, data, and video) typically supported by the technology

- **Standards:** Identifies the standards, or lack of standards, associated with the technology.

4.2 Technology and Service Characterizations and Comparisons

To analyze and compare the technologies and services, a set of matrices have been developed that include similar, comparable technologies, namely, transmission, circuit switched, and packet switched technologies. Within each matrix, the specific technology is measured against the individual analysis considerations. Analysis results are presented in short phrases that characterize how the technology relates to the particular consideration. In addition, technology comparisons are presented, when applicable. The technology evaluations are conducted for transmission technologies, circuit-switching services, and packet-based switching technologies and services (Exhibit 14).

Technology and Service C

	Transmission Technologies			Circuit S	
	Analog	**T1**	**SONET**	**Circuit (analog)**	**C**
Availability	• Implemented in private on-premise legacy analog systems	• Generally offered by carriers nationwide	• Implemented as trunking in major carrier networks and in private WANs	• Available nationwide	•
Bandwidth/ Capacity	• 300-3000 Hz • Potential data rates of 35 kbps	• Ranges from bundled 64 kbps to 1.544 Mbps	• Up to 10 Gbps	• Limited to 56 kbps	•
Physical Medium	• Predominantly copper	• Fiber; some copper	• Fiber	• Copper	•
Cost	• Installation, operations, and maintenance costs • Maintenance costs can rise steeply as systems age	• Lease Cost is based on distance and bandwidth and LATA boundaries	• Lease cost is based on distance and bandwidth	• Flat rate - $20.00/month	•
CPE	• Analog transmission equipment	• CSU/DSU and channel bank	• SONET transmission equipment	• Telephone set	•
Typical Implementation	• Point-to-point analog circuits supporting analog, legacy systems	• Leased point-to-point digital trunking in private networks	• PSN and WAN backbone, trend is to configure in SONET rings	• Rural residential	•
Applications Supported	• Voice, slow data, and slow scan video	• Voice, data, and compressed video	• Voice, data, and video	• Voice, fax, data (via modem)	•
Standards	• Interface standards uniformly adopted	• Interface standards uniformly adopted	• Interface standards uniformly adopted	• Established, uniformly adopted	•

5. COMMON WIRELINE TECHNOLOGY INTERFACED TO LMR SYSTEMS

Wireline technologies, and the corresponding networks and services, provide key capabilities to the public safety community. As wireline technologies continue to evolve, the public safety community must stay abreast of these changes to maximize their utility and effectiveness for use with LMR systems and public safety applications. Public safety LMR systems can leverage faster data rates, improved performance, and decreasing costs of wireline systems to improve overall communication capabilities. This report describes the wireline technologies embedded in legacy LMR systems and wireline technologies that system planners may consider as they plan for and design LMR system replacements.

Potential wireline technology solutions are varied and can be applied to a range of public safety requirements. Public safety users must analyze and tradeoff these solutions to identify the most appropriate solution for their needs. To conclude this report, a set of possible needs are presented and potential wireline technology solutions are applied. These needs, special considerations, and potential solutions are illustrated in Exhibit 15. This exhibit is intended to identify feasible, economic solutions to common networking needs; individual analyses should be conducted for specific public safety organization network needs.

Needs	Considerations	Potential Solutions
Connecting LMR components within public safety locations	▪ Part of a system upgrade or new system build ▪ Traffic expected to increase significantly ▪ Require link integrity to support range of applications ▪ Network, including wireline link, expected to be operational over 10 years	▪ Copper circuit is most effective solution for voice and control applications ▪ Fiber may be beneficial in future if LMR is part of integrated voice and data network in a large facility installation
Connecting LMR components between public safety locations	▪ Part of a system upgrade or new system build ▪ Traffic expected to increase significantly ▪ Organization prefers leasing over owning to avoid new build, management, maintenance, and technology refreshment costs ▪ Security is a requirement ▪ Network reliability / survivability is key feature	▪ Fiber circuits can support capacity, link integrity, and security needs ▪ Copper can support short distance circuits for limited traffic ▪ Specific transmission service (e.g., T1, SONET) availability depends on the telephone company network ▪ If traffic is expected to exceed 384 kbps (6x FT1), a full T1 tends to be more economical
Interconnecting LMR networks	▪ Digital systems installed in last 3 years ▪ Traffic may be minimal at first as users establish new traffic patterns ▪ Organization prefers leasing or owning to avoid new build, management, maintenance, and technology refreshment costs ▪ Security is a requirement	▪ Fiber may be required to support security needs ▪ Transmission-based services preferred, may seek ISDN transmission services to support different applications ▪ System planners need to work with the local telephone company to match needs with available services
Acquiring data services to communicate with remote offices and connect to agency databases	▪ WAN volumes projected to be between 64 kbps and 1.544 Mbps ▪ Fiber LAN installed ▪ Leasing is preferred option	▪ Switching-based, commercial service preferred to allow flexible routing to current and potential new offices ▪ Frame relay can support data only ▪ Dial-up circuits may offer reasonable cost depending on data rate required

Exhibit 15
Common Wireline Technology Needs and Potential Solutions

APPENDIX A
WIRELINE TECHNOLOGIES USED IN PUBLIC SAFETY TESTBEDS AND NETWORKS

The following are examples of how the public safety community is currently using wireline technologies to augment its current networks:

- Project 25 Demonstrations
- Iowa Project
- NCIC

Project 25 Demonstrations

The focus of Project 25 is to design and implement a set of open technical standards (TIA/EIA-102 suite of standards) for the next generation of land mobile radio (LMR) systems. The open interfaces include intrasystem and intersystem standards that provide a means to develop interoperable communications systems among federal, state, and local agencies. TIA-102 complient systems use wireline technology to interconnect radio system interfaces with remote databases. The open design of Project 25 radio systems' open standards ensures that wireline technologies such as integrated systems digital network (ISDN), X.25, and Internet Protocol (IP) can be used.

Project 25 LMR systems interface directly with the public switched network (PSN). The LMR subsystem interface with the PSN supports analog and ISDN telephone connectivity from mobiles or portables. LMR users can function much like any other user of the PSN, dialing calls directly from their touchpad. Using mobile data terminals, users can access the Internet and other resources interconnected to the PSN.

Iowa Project

The Iowa Project represents a series of evolutionary demonstrations designed to assess the effectiveness of integrating LMR architectures with other communications resources, including commercial wireless systems, external data networks and databases, and the PSN. The Iowa project uses leased wireline technology and circuits from a synchronous optical network (SONET) -based, high-speed, statewide data network, the Iowa Communications Network (ICN).

The ICN, illustrated in Exhibit 18, is the backbone network for the Iowa Project demonstrations. This state-owned network is a high-speed network using Digital Service (DS) 3 fiber optics. The network extends throughout Iowa and connects multiple Iowa Department of Public Safety (DPS) facilities, and other Iowa State agencies . The ICN uses wireline technology to support interoperability among wireless networks, wireless data networks, and the PSN.

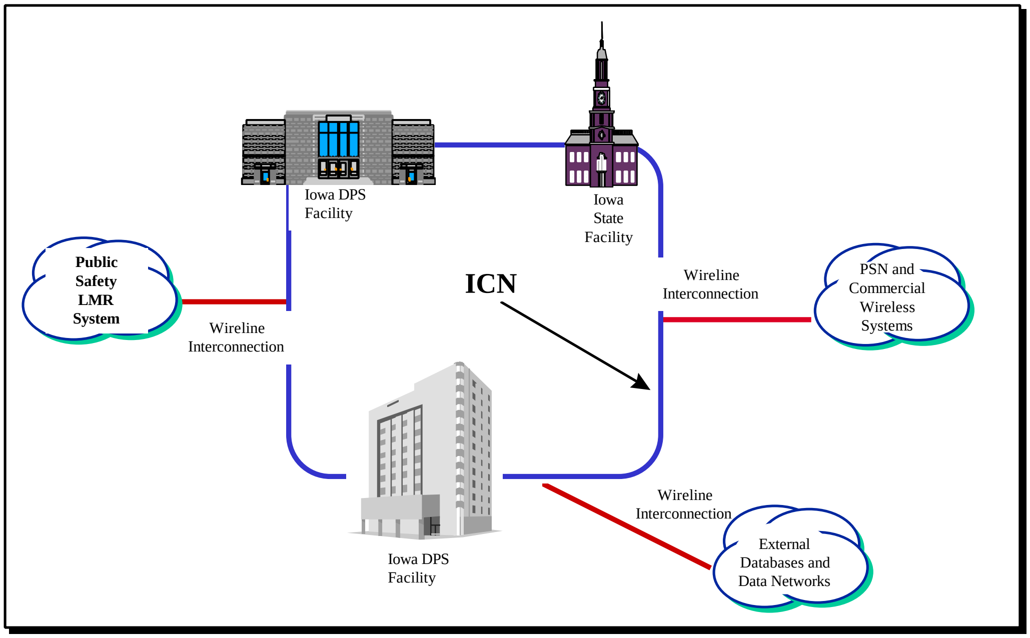

Exhibit 18
ICN Network Structure

Wireline technology is also used to connect wireless communications networks to external databases. For example, the Iowa Project links radio systems to the National Criminal Information Center (NCIC) database using wireline technology. Wireline technologies, such as frame relay switching, interconnect a wireless system gateway to state databases that are interconnected to the NCIC.

National Crime Information Center (NCIC)

NCIC is a network of national crime information databases accessible by law enforcement agencies through interconnected local, state, and federal computer systems. It has direct connectivity to the Federal Bureau of Investigation (FBI) crime information center, which is the repository of criminal profiles and histories. The system also has connectivity to the Department of Motor Vehicles (DMV) information in all 50 states and contains plate, driver, vehicle identification numbers, and other auto-related data. Currently, the FBI is developing a new system to replace the existing NCIC system. The NCIC 2000 system will increase capacity, update technology, and add fingerprint and image processing capabilities.

The central segment (CS) is the hub of the NCIC 2000 system where the main processing occurs. The NCIC CS supports the communications protocols used by wireline technologies such as IP and X.25. State computing facilities will link to the NCIC 2000 using these wireline technologies.

An objective of NCIC 2000 is to provide seamless data transmission to mobile public safety officials. Using mobile data communications such as cellular digital packet data (CDPD), police officers are able to perform a variety of database queries from the patrol car. To support this type of access, wireline technology is used to connect wireless data network users to the NCIC. NCIC wireline technologies and interconnections are illustrated in Exhibit 19. For example, CDPD subscribers accessing the NCIC database are connected to a local telephone company's circuit switch via wireline technology. Wireline technology interconnects the cellular network to the switch so that the user may access state and federal resources interconnected to the PSN. In most cases, the state computer network is connected to the PSN. CDPD users typically access the NCIC databases via their state's computer networks.

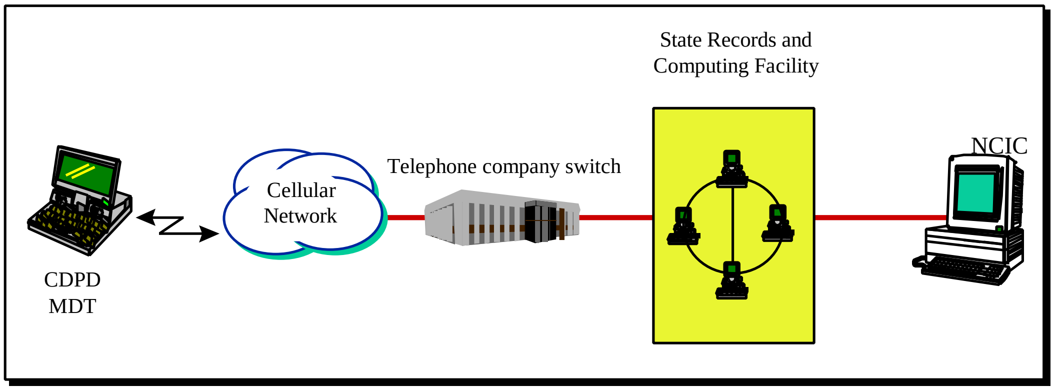

Exhibit 19
NCIC Wireline Connections

APPENDIX B
LIST OF ACRONYMS

ATM	Asynchronous Transfer Mode
BER	Bit Error Rate
BRI	Basic Rate Interface
CDPD	Cellular Digital Packet Data
CEB	Communications Electronics Board
CIR	Committed Information Rate
CPE	Customer Premise Equipment
CS	Central Segment
DARPANET	Department of Defense Advanced Research Project Agency Network
DMV	Department of Motor Vehicles
DPS	Department of Public Safety
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission
Gbps	Gigabytes Per Second
ICN	Iowa Communications Network
IP	Internet Protocol
ISDN	Integrated Services Digital Network
kbps	Kilobytes Per Second
LAN	Local Area Network
LMR	Land Mobile Radio
Mbps	Megabytes Per Second
MSC	Mobile Switching Centers
MSS	Mobile Satellite Services
NAVSTA	Naval Station
NCIC	National Criminal Information Center
NSFNet	National Science Foundation's Network
OC	Optical Carrier
PCS	Personal Communications Services
POTS	Plain Old Telephone Service
PRI	Primary Rate Interface
PSN	Public Switched Network
PSWN	Public Safety Wireless
RCS	Regional Communications System
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Network
TDM	Time-division Multiplexing
USN	United States Navy
VPN	Virtual Private Networks
WAN	Wide Area Network